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BERKELEY, CALIFORNIA

CALIFORNIA COTTON INSECTS

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BULLETIN 660
January, 1942

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

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CALIFORNIA COTTON INSECTS[1]

GORDON L. SMITH[2]

COTTON PRODUCTION in California has increased rapidly during the past few years, but plantings in Riverside and Imperial counties have decreased chiefly because of the difficulties encountered from insect pests of cotton. Many of the insects attacking cotton in California are pests throughout the southwestern states and Mexico, yet they have not been studied so thoroughly as the cotton insects of the southeastern United States. A serious outbreak of plant bugs and other insects occurred in the San Joaquin Valley during the summer of 1935, and investigations of the insect problems of cotton were started in September of that year. As an initial step it was considered advisable to determine the distinguishing characteristics of the injuries caused by the various species. The information obtained is essential for diagnosis and evaluation of the damage. Both growers and workers in fields allied with entomology should find this work of practical value.

IMPORTANT COTTON INSECTS

COTTON DAUBER

The cotton dauber, *Lygus hesperus* Knight (fig. 1) is $\frac{7}{32}$ inch long and one third as broad. The females are straw-colored, the males darker with red and brown markings on the wings, body, and appendages. The intensity of these colors varies considerably. The overwintering males are nearly mahogany, the females reddish. The greenish-yellow, heart-shaped mark between the bases of the wings helps to identify this insect on cotton. They are more readily observed during the cooler hours when they are less active.

The long, slender mouth parts are used to pierce the soft tissues and suck the sap, and the eggs are forced into this tissue with a saberlike ovipositor. A very small elliptical opening is left on the surface of the stem when an egg is deposited, through which the young nymph emerges after 7 to 12 days of incubation. There are five nymphal instars before the adult appears. The nymphs (fig. 1, *B, C,* and *D*) are pale green in color with red on the antennae; the third, fourth, and fifth instars have circular black spots on the upper surface. Cotton growers sometimes mistake these for aphids, but they are much more active when disturbed, and the red antennae as well as the more slender bodies distinguish them from aphids.

[1] Received for publication March 13, 1941.

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During the months of July and August, under the temperature conditions at Shafter, California, the adult stage is reached about 30 days after the eggs are deposited. The adults mate at dusk, dawn, and probably during the night. They have been observed mating in the daytime only in the laboratory when sexes were kept segregated for about 5 days after the last molt. Observations of mating in the field have been made only three times during four seasons of study. Adults live from 40 to 45 days during the summer in confinement on cotton, and an average of three nymphs per day are produced by eggs from each female. The females oviposit or attempt oviposition so much more often than the pro-

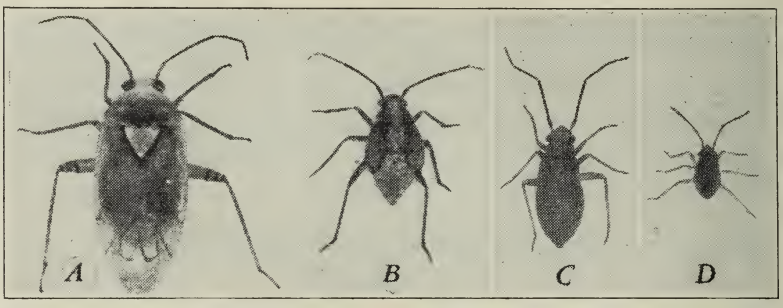

Fig. 1.—The cotton dauber, *Lygus hesperus* Knight: *A*, adult; *B*, fifth instar; *C*, fourth instar; *D*, third instar. (All×5.)

duction of nymphs indicates that there may be some unknown factor which accounts for the small numbers obtained in thin cloth cages over cotton branches. No internal parasites have been found, but many predatory insects and common spiders do attack the cotton dauber.

The insect is called the cotton dauber because of the circular spots of excrement which it leaves on the plant. These spots, or daubs, are $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter, shiny yellow at first but gradually darkening; they first occur on the tender parts of the cotton plant.

The group of insects including the cotton dauber may be designated as "tarnished plant bugs," "*Lygus* bugs," and "legume bugs." These are known as pests of deciduous fruits, alfalfa seed, potatoes, beets, and many other crops as well as cotton.

Injury.—The cotton dauber has been found to be the most serious insect pest of cotton in the San Joaquin Valley. Other insects may be more serious in some fields and in certain years, but this species has been found in all localities during the years 1935 to 1940. Variations in infestations of cotton daubers and the loss of crop in 1938 as compared with 1937 were great throughout the San Joaquin Valley. In areas where

other succulent crops such as alfalfa and potatoes were close to cotton, greater losses occurred than in those areas which had little other succulent growth near by. At the United States Department of Agriculture Cotton Field Station at Shafter, the population of the cotton dauber was much higher during the early part of the season in 1938 than in 1937, and the first picking of seed cotton was 36.5 per cent lower. The total yield was 23.8 per cent less for 1938 than for 1937.

Fig. 2.—The cotton burs to the left show gall tissue produced by the cotton dauber. Those to the right show gall tissue produced by puncturing small bolls with fine needles. The desired type of boll is shown at the center.

Injury due to the feeding of both adults and nymphs results in:

1. Increased drop (shed) of buds (squares), flowers, and small bolls (fig. 4).
2. A later crop, much of which is not mature when frost, rains, and freezing temperatures occur.
3. Cell proliferations (gall-like tissue) in bolls which cause the lint to cling to the bur, or exocarp (figs. 2, 3).
4. Destruction of seeds by puncturing and extracting their contents in early stages of development (fig. 5).
5. Tagging (parts of locks being left in the burs) because of destroyed seeds and abnormal opening of the boll (fig. 2).
6. Weak, fuzzy, and discolored lint (fig. 5).
7. Reduced oil content of seeds.
8. Reduced germination of seeds.

9. Deformed plant growth, which is less productive (fig. 4, *A*).

As methods of determining the presence of this insect and its injury to cotton, the following are suggested:

1. Look for injured flowers, which are deformed and show darkened areas of any or all floral parts (fig. 6).
2. Look for oviposition scars, especially on the leaf stems (petioles) at the base of the leaf blade.

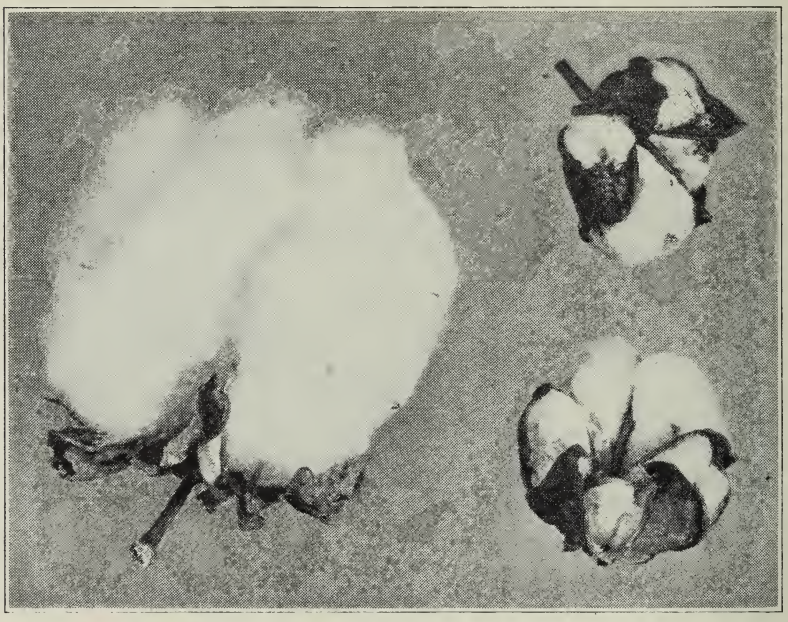

Fig. 3.—The two burs at the right show locks of cotton lost because of injury by the cotton dauber; at the left is an uninjured boll.

3. Look for circular shiny spots of excrement on the squares, stems, and flowers which flare or fall (fig. 6).
4. Hold a card, cloth, hat, or the like horizontally beneath the tips of branches and shake the branch against it to dislodge the small green nymphs with reddish antennae.
5. Look for adult insects around flowers and squares about sunrise and sunset.
6. Open green bolls, one-half to three-fourths grown, remove the locks, and examine the inner bur surface for white warty protuberances. Examine at least 100 locks (approximately 20 bolls). If 15 per cent of these show injury, a considerable loss may be expected.

7. Watch the setting of the crop; if on a single fruiting branch, bolls are missing from two or more nodes that should have them, the shed has been excessive (fig. 4).

The injured fruiting forms do not always fall from the plant and those remaining may show little early injury, but with subsequent growth the tissues become gall-like. The seed from cotton plants grown in large cages containing cotton daubers was sent to the California Seed Labora-

Fig. 4.—*A*, Extensive cotton-dauber injury on experimental cotton plant; *B*, typical field plants showing areas of greatest shed caused by cotton dauber during the period from July 15 to August 15, 1938. Moderate, rank, and short growths shown.

tory in Sacramento for germination tests. Of this seed only 74.4 per cent germinated, whereas 97.0 per cent of the seed germinated from plants in the same type of cages where insects were excluded. Experiments in 1939 and 1940 show that the puncturing of buds and very small bolls with fine sterile needles will cause 74.4 per cent of the buds and flowers and 69.4 per cent of the small bolls to fall. The bolls that were punctured with a sterile needle and developed showed an abnormal proliferation of cells at the point where the needle penetrated the inner bur (carpel) surface. The injury produced by the needle punctures is very similar to that produced by an insect puncture. The degree of injury was not so extensive as that usually produced by insects, which probably indicates that the insect makes more punctures than were made with the needle. J. T. Barrett of the University of California examined the gall tissue

produced by cotton daubers and found no organisms present in the tissue.

Control.—The many host plants of this insect make control by cultural practices difficult. The following practices are of value in decreasing the amount of damage.

Fig. 5.—The cotton-dauber injury to fiber and seed. Upper left, a lock wth 3 seeds destroyed; lower left, normal seed; lower right, shriveled, rough seed; upper center, portions of burs to which fiber clings; lower center, lock containing only 2 good seeds; right, degrees of fiber and seed destruction.

1. Cut alfalfa as frequently as is practical. Cut only portions of the field, so that some is always succulent and growing vigorously when another part is being cut.
2. Cut alfalfa early, just before the first hay crop starts growth. Preceding this cutting by pasturing and cultivating should help destroy the adult insects that overwinter in these fields. About March

20 a few of the overwintering adults are alive, but many nymphs and eggs are present, which makes this an excellent time to destroy them by cultural practices.

3. Destroy all early weed growth in and around cotton fields, especially during April and May.
4. Clean up weedy areas in November by plowing, burning, and similar methods.

During December, January, and February the overwintering cotton daubers are most numerous in alfalfa fields but are also found on cover-

Fig. 6.—Cotton flowers injured by the feeding punctures of the cotton dauber.

crops, mustard, legumes, and weeds. Grasses and grains are of relatively little importance as host plants. The adults deposit eggs in the succulent stems and disappear about March 20.

Both insecticidal dusts and sprays have been used in experimental work to control cotton daubers on cotton. Dusts are more easily applied to cotton because less weight is involved in both materials and machines and the supply of water for sprays is difficult to obtain in most cotton fields. An insecticide in either dust or spray form should not be applied to cotton between approximately sunrise and midafternoon, unless the grower is willing to sacrifice the crop from the flowers for that day. Tests in 1939 and 1940 showed that more than 99 per cent of the flowers dusted or sprayed soon after opening produced no bolls. Water and road dust were just as effective as insecticides in preventing the fertilization of flowers.

Of nine dusts tested, a sulfur and paris green mixture (12:1) or a dust of sulfur two thirds and calcium arsenate one third has given the greatest increase in yield and the most satisfactory control of nymphs.

The results obtained from the use of sulfur alone have varied greatly. In 1936 an increase of 3.2 per cent in yield of seed cotton was obtained. In 1937 no increase was found and in 1938 four plots showed increase of from 0.5 to 16.4 per cent. In 1940 three applications of sulfur dust gave a 14.9 per cent increase in yield. Several other materials which are being tested offer some promise of efficient control of this insect.

If good farm practices are not followed, if land is poor, if sources of reinfestation by cotton daubers and other insects are not eliminated by the practices suggested, or if growing conditions in general are not good, the use of an insecticide cannot be expected to show much value, if any, in terms of increased yields.

BLACK COTTON FLEAHOPPER

A small, black leaf bug, *Chlamydatus associatus* Uhl., designated as the black cotton fleahopper (fig. 7) because it is about the same size as the cotton fleahopper, *Psallus seriatus* (Reut.) (fig. 8), and has similar habits, is the second most common of the leaf bugs found on cotton in the San Joaquin Valley. The burweeds, *Franseria* spp.—members of the ragweed tribe—are preferred host plants in the San Joaquin Valley. When this insect was found breeding on cotton, it was segregated in cages where it lived and reproduced on cotton throughout the season. This insect had not been reported previous to 1936 as a pest of cotton so far as is known.

Fig. 7.—The black cotton fleahopper, *Chlamydatus associatus* Uhl. (×10).

The adults are ⅛ inch long and about one third as broad, black in color except for the legs and the antennae, which are white; the nymphs are dusky green with white antennae and legs. The adults are found most frequently in flowers during July and August. They are so active during the warmer hours of the day that they are seldom observed but may be seen in the early morning. The nymphs may be collected by the same methods used to collect cotton-dauber nymphs. The eggs are laid in the stems of burweed and cotton. The overwintering eggs in the dead dry stems of burweed collected during the winter hatch during the first 20 days of April. No nymphs have been obtained from dry cotton stems. Adults are found on cotton from May 1 through the growing season, becoming scarce in September.

Injury.—The nymphs and adults of the black cotton fleahopper occur on the more succulent leaves, buds, flowers, and stems of cotton. The injured leaves become ragged or curled, and irregular holes are produced in the leaves as they grow. This type of injury is so similar to that done by the western flower thrips that on seedlings in the field the two are indistinguishable. In cages the black fleahopper has caused increased motes (undeveloped seeds), 22 per cent; increased loss of fiber weight, 26 per cent; and increased shed, 3 per cent, as compared with uninjured plants. Premature opening of bolls, weak fiber, and numerous motes are the most serious forms of injury. The stem lesions and ragged leaves probably do not greatly affect total yields.

Fig. 8.—Adult cotton fleahopper, *Psallus seriatus* (Reut.) (× 10).

The growing conditions for cotton were very good during the 1939 season, and cotton daubers, worms, and stink bugs were of less importance than usual, though there was scattered, light injury from red mites and bean thrips on cotton at the Cotton Field Station. The yield of seed cotton at the Station increased 17.2 per cent over 1938—a year of considerable loss by the cotton dauber—but was 10.8 per cent under 1937.

From 1936 to 1938 the black fleahoppers on cotton were about one tenth as numerous as were the cotton daubers. But in 1939 black fleahoppers were more numerous than they were the preceding three years. In late August when cotton daubers were found more numerous than they were earlier in the season, these fleahoppers were equal to and frequently exceeded the number of cotton daubers. The increase in black fleahoppers, combined with a 25 to 45 per cent increase in bushy plants caused by western flower thrips, and some little injury from red mites and bean thrips, may account for the loss in 1939, which cannot all be attributed to cotton daubers.

Control.—The destruction of burweeds is recommended for the control of this insect. The eggs can be destroyed by burning burweeds when they are dead and dry in the fall and winter, and if the spring growth near cotton fields is destroyed, the chief source of infestation will be removed.

COTTON FLEAHOPPER

The adults of the cotton fleahopper, *Psallus seriatus* (Reut.), are 1/8 inch long, about one third as broad, and gray green in color with very fine black specks uniformly distributed over the body and appendages (fig. 8). The tiny pale-green nymphs may be distinguished from cotton-dauber nymphs by the lack of red on the antennae, the third, fourth, and fifth instars being fairly distinct because of the presence of fine black

Fig. 9.—*A*, Types of deformed and fruitless plants produced by cotton fleahoppers; *B*, stem lesions produced by cotton fleahoppers.

specks. The insects occur in great numbers on turkey-mullein, *Eremocarpus setigerus* Benth., and on *Croton californicus* Mull. Some are found on alkali mallow, *Sida hederacea* (Dougl.) Torr., and evening primrose, *Oenothera* spp. This insect is a serious pest of cotton, especially in Texas, and is mentioned frequently in the literature on cotton pests throughout producing sections of the United States. It is found on its native host plants throughout the San Joaquin Valley. Adults are sometimes numerous on cotton in April and May, but nymphs have not been found in large numbers on cotton in the San Joaquin Valley.

Injury.—Cotton fleahoppers segregated in cages on cotton reproduced there and injured the plants seriously (fig. 9, *A*). They caused small

squares to shed, caused deformed plants and scarred leaf and stem tissue (fig. 9, *B*), and decreased the yield.

Control.—The abundance of the preferred weed host plants in the San Joaquin Valley may account for the fact that the cotton fleahopper is a minor pest there. A complete study of this insect was made by Reinhard[3] in Texas. Eddy[4] reported on its abundance, injury, and control on cotton in South Carolina. Control studies have been numerous, and the more recent ones by Ewing and McGarr[5] give a mixture of sulfur and paris green (9:1) as the most effective of fine dusts tested for control of this insect.

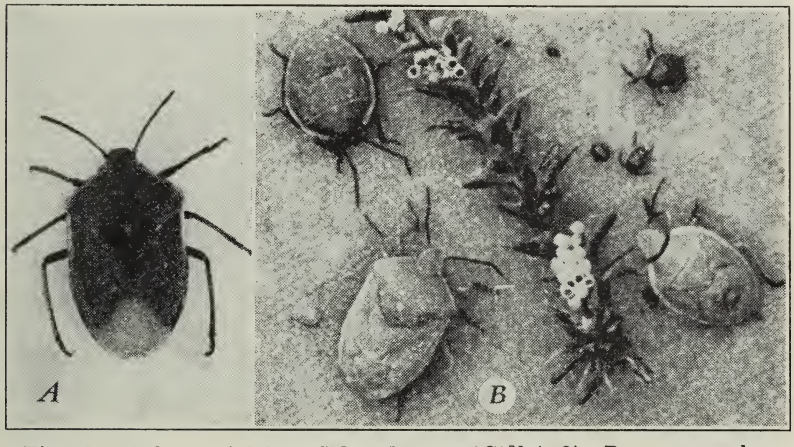

Fig. 10.—*A*, Say's stink bug, *Chlorochroa sayi* Stål (×2); *B*, eggs, nymphs, and adults (×2).

SAY'S STINK BUG

Say's stink bug, *Chlorochroa sayi* Stål (fig. 10), is one of the most important pests of cotton in California. In Imperial and Riverside counties it is apparently destructive every year but rarely becomes epidemic throughout the San Joaquin Valley.

The adults are about ½ inch long and 5/16 inch broad, but vary considerably in size. They are light sage green except during the winter when they become bronze or a darker green and these change to a lighter green when they begin feeding on plants in the spring. Three rather prominent, light, callouslike spots in a straight line across the back be-

[3] Reinhard, H. J. The cotton fleahopper. Texas Agr. Col. Bul. 339:1–40. 1926.

[4] Eddy, C. O. Cotton fleahopper studies of 1927 and 1928. South Carolina Agr. Col. Bul. 251:1–18. 1928.

[5] Ewing, K. P., and R. L. McGarr. Recent insecticide experiments to control cotton flea hopper at Port Lavaca, Tex. Jour. Econ. Ent. 30(1):125–30. 1937.

Ewing, K. P., and R. L. McGarr. Large-scale sulfur-dusting experiments for flea hopper control at Port Lavaca, Tex. Jour. Econ. Ent. 30(1):130–34. 1937.

tween the bases of the wings help to identify this insect on cotton in the San Joaquin Valley. The antennae are black except at the base.

An average of 150 eggs is laid by each female. The eggs are laid in clusters (fig. 10, *B*), usually 28 in a cluster, although wide variations occur. Multiples of seven are most commonly found. These eggs resemble small, banded kegs, ivory in color with gray, circular bands. In the spring, incubation may continue for 15 days, but in July the eggs may hatch in 5 days.

The nymphs (fig. 10, *B*) are black and white in the first and second instars; black, green, and yellow or orange, in the third; sage green with black and white spots and yellow or orange margins, in the fourth and fifth. The wing pads show slightly in the fourth instar and prominently in the fifth. The first instar is $\frac{1}{16}$ inch long and nearly as broad; the third, $\frac{1}{8}$ by $\frac{3}{32}$ inch; the fifth, about the same size as the adult. Immediately after molting, the nymphs are flat, but before molting they are very convex. The duration of nymphal instars varies with the time of the season.

Overwintering adults live about eight months and those which develop in the spring and summer live two to three months. Adults which laid eggs in September have been kept in an outside screen house until the following March, but under such conditions no eggs were laid by these individuals in the spring. The last of the overwintering brood live until late May. Any female of this brood may mate and lay eggs at various times from late February to the last of May. The only time during the year when adults are scarce is from approximately May 15 to June 15. In confinement the adults feed on their eggs if desirable plant food is scarce and produce light-colored eggs with chorion processess. The males feed on the eggs more frequently than do the females.

There is a close association of this insect with grains and tumbleweeds and similar plants. Their principal food consists of seeds. In late February and during March they are most numerous around weedy areas, where they crawl from beneath the protective covering (especially from beneath Russian thistles, *Salsola Kali* var. *tenuifolia*) and go to brome or other grass heads to feed on the seeds. If the temperature reaches 70° F or more they frequently fly. These flights may be for short distances but some rise 30 feet from the ground and disappear in the distance. They are found most abundant on heads of grain during April, May, and June, but are also found feeding on flax, potatoes, alfalfa, *Amaranthus* spp., *Chenopodium* spp., sugar beets, and other plants.

A small wasp, *Telenomus mesillae* Ckll., parasitizes the eggs of Say's stink bug. This parasitism destroys about 48 per cent of the eggs in an

average year; it is light in the spring but increases rapidly during the hot summer. Tachinid flies parasitize only 3 to 5 per cent of the adults.

Injury.—The habit of feeding on developing seeds makes this insect a very serious pest of cotton. Injury rarely appears before the middle of July, at the time small grains ripen and are harvested. A very few insects may do considerable damage to the crop because they feed on so many bolls in various stages of growth. The bolls which the adults feed

Fig. 11.—Some of the types of injury of cotton bolls due to Say's stink bug. An uninjured boll at upper right.

on are usually well set and do not fall from the plant, but nymphs cause many small bolls to dry and fall. The punctures made by the mouth parts are numerous and cause yellow, rough, proliferated cell areas on the inner bur surface accompanied by shriveled seeds, stained fibers, and eventually hardened, dry locks of unpickable fiber (fig. 11). Fungi that cause boll rot[6] are sometimes introduced by this insect, although other insects are more often responsible. The amount of injury varies greatly within a field and within districts. In areas where Say's stink bugs are numerous in grainfields, they may move to or remain on tumbleweeds in or around the grainfields throughout the remainder of the

[6] Shapovalov, M. The two most common decays of cotton bolls in the southwestern states. Jour. Agr. Res. 35(4):307–12. 1927.

season (or most of the season) and few can be found in near-by cotton fields.

Control.—The behavior of these insects, particularly their growth and development, indicates their preference for plants other than cotton.

Thus, it is inadvisable to destroy these preferred host plants at the time when cotton bolls are developing (late June to October), but instead they should be destroyed together with the insects that are on them in the early winter, spring, and in grainfields immediately after the harvest of the grain.

Burning weedy areas after the first killing frosts in the fall, followed by plowing or burning of grain and grain-sorghum fields after harvest, and destroying weeds in May when most of the stink bugs are wingless nymphs are the practices recommended for the control of this insect. These procedures also reduce the fire hazards and destroy numerous other insects of economic importance which hibernate in these same areas, or are breeding on weeds.

Some farmers are following the practice of removing unnecessary fences, plowing or burning stubble fields immediately after harvest, cleaning up fields, borders, roadsides, and ditchbanks, but they need the coöperation of the road crews, railroads, irrigation companies, and other farmers. The areas where the native growth has been destroyed and replaced by weeds are the only places which need this attention. For example, a campaign for this purpose was organized at Blythe, California, and though not all that was hoped for was accomplished the first time (1937–38), the results observed during the cotton season of 1938 were encouraging, and the program is being continued. The chief weed host plant there is the five-hook bassia, *Bassia hyssopifolia* (Pall) Kuntze, a tumbleweedlike plant which is now becoming established in the southern San Joaquin Valley.

Several factors make it difficult and impractical to use chemicals for the control of Say's stink bugs on cotton in the San Joaquin Valley. First, the insecticides for the control of cotton daubers should be applied before the time that stink bugs migrate into the cotton fields. Second, the insecticides that will give sufficient control will probably be too expensive to justify their use except in rare cases. And finally, the adults migrate to cotton from preferred hosts and probably would continue to do so even though insecticides were applied to the cotton.

Many dusts and sprays have been tested in studies of control methods for Say's stink bug. Dinitrophenol-sulfur dusts[7] have given considerable

[7] Dinitro-o-cyclohexylphenol (1 per cent) in walnut-shell flour, and 50 per cent sulfur.

promise. These materials have been used in cotton fields for the control of other insects and mites, without serious injurious effects. They have been tested in field plots in only a few cases for control of Say's stink bugs. In large screen cages over cotton they have given a high percentage of kill for both adults and nymphs. Until more investigation of the staining effect of dinitro dusts on cotton is completed, the dusts should not be applied at or after the time that bolls are ripening, that is, after mid-August.

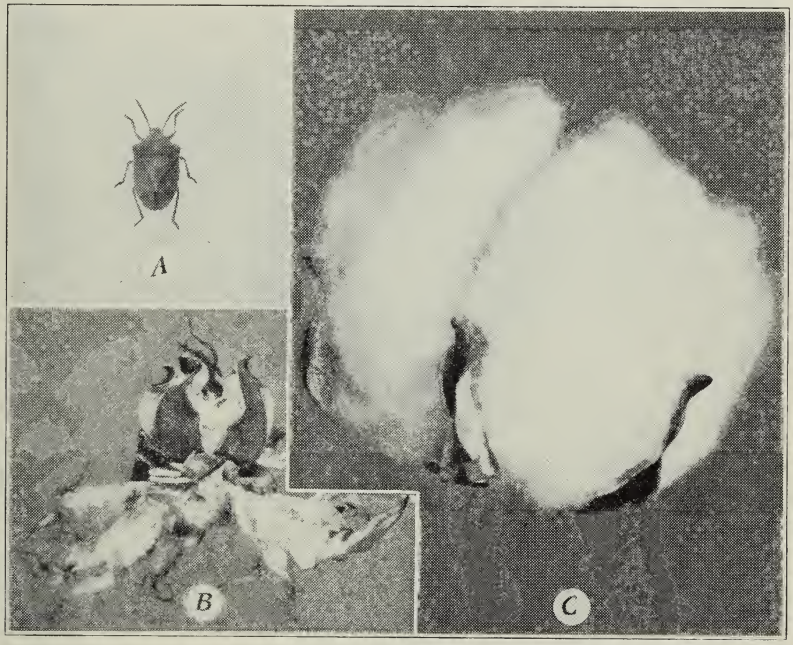

Fig. 12.—*A*, The red-shouldered plant bug, *Thyanta custator* (Fab.) (actual size); *B*, small cotton boll injured by the red-shouldered plant bug; *C*, a normal boll.

Sprays containing oil and pyrethrum have shown promise, but many stink bugs recover. No plant injury has been found due to small amounts of oil used in dust mixtures, nor from certain oil sprays correctly applied.

Tests have shown that a dust mixture of paris green and sulfur is not effective for controlling Say's stink bug.

RED-SHOULDERED PLANT BUG

The red-shouldered plant bug, *Thyanta custator* (Fab.) (fig. 12, *A*), has much the same habits as Say's stink bug and is found on the same host plants. It is about two thirds the size of Say's stink bug, roughly

7/16 inch long and 1/4 inch broad. Late summer and overwintering adults are frequently tan or brown, and the first seasonal brood is usually a bright green with sometimes a red band or stripe across the back above the bases of the wings. They usually lay about 40 eggs in a mass; these hatch in from 3 to 5 days when temperatures range from 85° to 95° F. They reach the adult stage in 15 to 35 days after oviposition, the length of time depending on both temperature and availability of food. The first-instar nymphs are black or dark brown and white. The other instars are checkered with about equal amounts of brown and white. The antennae are red.

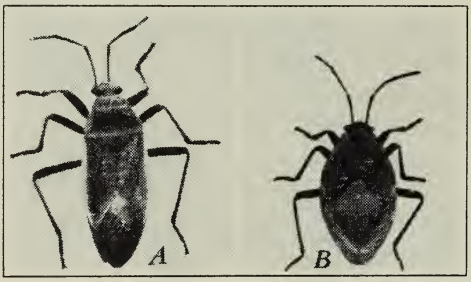

Fig. 13.—The bordered plant bug, *Euryophthalmus convivus* (Stål): *A*, adult, and *B*, fifth-instar nymph. (Both × 2.)

Injury.—Injury to cotton (fig. 12, *B*) by this insect is the same as by Say's stink bug except that, for equal numbers of the two, the red-shouldered plant bug is more serious.

Control.—The scarcity of these bugs under most conditions in California makes it highly improbable that any special control measures will be needed. The eggs are highly parasitized and the control for Say's stink bugs will probably also control this species.

BORDERED PLANT BUG

The adult females of the bordered plant bug, *Euryophthalmus convivus* (Stål) (fig. 13, *A*), are 1/2 inch long and 3/16 inch broad; the males are narrower. They are velvety gray brown in color with orange borders on the pronotum and basal portions of the wings. The membranes of the wings are quite dark. Scattered fine specks of orange are evident by close examination. The color of the broad oval nymphs (fig. 13, *B*) is a metallic, dark blue black with a bright-red spot near the center of the back. This insect has been found only a few times injuring cotton, but the injury was very severe. All stages of the insect were found present on injured cotton plants. In all cases they were found on cotton along

watercourses, but they are also found on berries on dry slopes. It is most frequently a pest of berries.

Injury.—Its feeding punctures in bolls form gall tissue, and seeds and fiber are destroyed. It is so seldom found on cotton that it has not been thoroughly studied.

Fig. 14.—The adult female of the bean thrips, *Hercothrips fasciatus* (Perg.) (× 75). (From Bul. 609.)

BEAN THRIPS

The bean thrips, *Hercothrips fasciatus* (Perg.) (fig. 14), has been studied so thoroughly by Bailey[8] during the past few years in California that it is unnecessary to repeat the work here. The adults are slender and only $\frac{1}{25}$ inch long, black with white bands across the back of the wings. The first-instar larvae are pale, slender wingless insects which are difficult to see without the aid of a lens. The second-instar larvae (the mature larvae) are deep pink to orange in color and the same size as the adults. This insect may be easily identified through the injury it does.

[8] Bailey, Stanley F. The bean thrips. California Agr. Exp. Sta. Bul. 609:1–36. 1937.
Bailey, Stanley F. Thrips of economic importance in California. California Agr. Exp. Sta. Cir. 346:33–40. 1938.

Injury.—The sucking mouth parts are forced into the tissues of leaves and sometimes of soft stems and produce white stippled areas (fig. 15). The excrement occurs as black spots on this whitened surface. The cotton leaf turns silvery where this insect has fed extensively and gradually becomes dry, brown, and falls from the plant. Thus the plant is deprived of necessary leaf surface and suffers in proportion to the foliage lost (fig. 16). Squares, flowers, and small bolls drop from injured plants. If

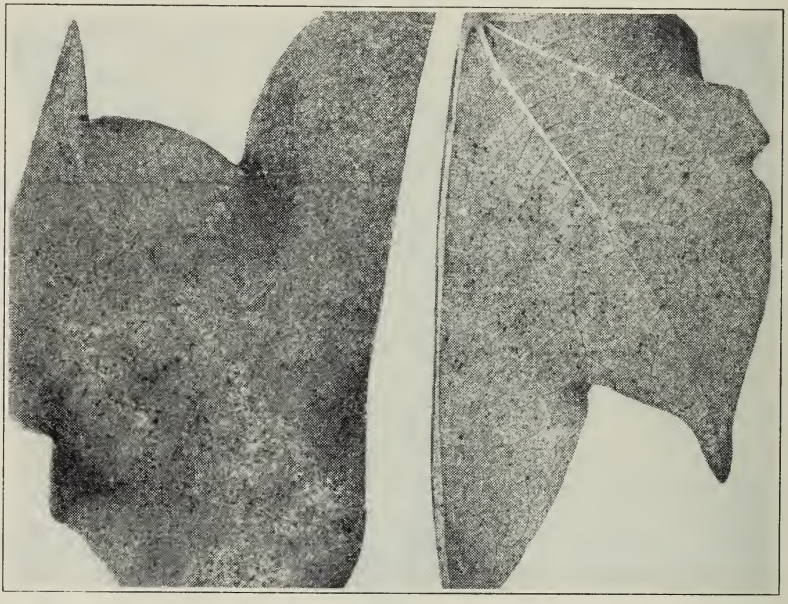

Fig. 15.—Bean-thrips injury on the upper and lower surfaces of the same cotton leaf.

the injury is severe, no further production can be expected, and the bolls formed may open prematurely, which results in low-grade fiber.

Cotton growing on heavy dark soils shows bean-thrips injury more than cotton on lighter soils; and where water penetration of the soil is poor, cotton shows injury more than that in other soils. Hot, dry periods favor the development of the insect, and during such weather cotton may show a sudden change in color owing to bean thrips and drought. Growers often interpret this as a sudden migration of thrips from some other place into their fields. Bean thrips and their injury may be found on cotton in some degree, from the seedling stage on to frost. Winds carry the adults, and infestations can be traced from near-by fields from which the prevailing winds have brought many adults.

In the southern San Joaquin Valley the earliest date for the appearance of bean-thrips larvae is March 21. Serious injury usually occurs on cotton in August. In areas where bean thrips are usually important pests, a grower should examine the lower surface of the older leaves on a plant early in July to determine the necessity for control. It is useless to combat thrips after serious injury occurs to plants.

Control.—It has been demonstrated that in the San Joaquin Valley this thrips can be satisfactorily controlled by weed eradication alone.

Fig. 16.—Cotton plants defoliated by bean thrips.

The important weed hosts are the prickly lettuce, *Lactuca scariola* L., and the common sow thistle, *Sonchus oleraceus* L., frequently called "milkweeds." These are common, introduced weeds found throughout the San Joaquin Valley on soil where the native growth has been destroyed. In western Stanislaus County, beans have been satisfactorily protected from this pest by removing these two weeds.

Irrigation methods in cotton fields where bean-thrips injury occurs, can greatly reduce the damage. In some cases, however, this procedure may be more expensive than applying an insecticide. In irrigating to reduce bean-thrips injury, care should be taken to thoroughly wet the entire soil surface beneath the plants.

Leaves of cotton were examined before and after insecticides had been applied by airplane to determine the number of living and dead bean-thrips larvae on a unit leaf area: seldom could any of the insecticide be found on the lower surfaces though the upper surfaces were well covered. Some few larvae are found on the upper leaf surfaces, and the kill

of these with any of several contact insecticides is high. In 1937 cotton dusted with sulfur twice in August, by airplane, for bean-thrips control, showed an increase in yield for the late pickings, but none for the first picking. Sulfur applied as an insecticide for bean thrips, cotton daubers, and cotton fleahoppers has given increases in yields of seed cotton with insufficient reductions in numbers of insects to account for it.

A major problem of the control of bean thrips and all other cotton insect pests is the method of application of the insecticide. To obtain a

Fig. 17.—Western-flower-thrips injury to cotton seedlings.
(From Cir. 346, photograph by G. L. Smith.)

coverage which should be expected to result in good control, machines adapted for use in irrigated cotton are needed. When good coverage of the leaf surface has been obtained, dinitrophenol[9] dust has given a very high percentage of control of bean thrips. It has more promise than other dusts tested for the control of this insect on cotton.

WESTERN FLOWER THRIPS

This insect, *Frankliniella occidentalis* (Perg.), is known by several common names, including "western thrips" and "grass thrips," but western flower thrips is preferred to avoid confusion with other species. The adults are slender, straw-colored, and little more than $\frac{1}{25}$ inch long. The nymphs are pale, cream-colored, and the second instar is the same size as the adults. They are found in flowers of almost every kind and cause flower, fruit, and bud injury. They occur on cotton throughout the season.

[9] Dinitro-o-cyclohexylphenol and also the dicyclohexylamine salt of this material.

Injury.—In April when cotton is starting to grow, the western flower thrips is found in great numbers in the first leaf buds where they feed on the inner surface of the leaves (fig. 17). Growth is retarded, and ragged cupped leaves are produced. The scarred areas, which do not grow normally, cause the outer edges to curl up and in, a characteristic that distinguishes it from aphid injury, which causes a leaf to curl down at the edges. Serious injury completely kills the buds and results in a bushy plant.

Fig. 18.—*A*, Bushy cotton plant caused by the killing of seedling buds by western flower thrips; *B*, an erect type which grew adjacent to this bushy one.

Bushy plants have no central erect stalk (fig. 18, *A*), as does the normal type of plant (fig. 18, *B*), and they bloom about two weeks later. They may eventually produce as many bolls as adjacent erect plants but the bolls are lighter, smaller, and later; and a greater percentage of four-lock bolls appear on bushy plants. Usually there are 15 to 25 per cent bushy plants in many cotton fields in the San Joaquin Valley; in 1939 the bushy plants averaged 45 per cent. Seed cotton picked from 15 each of bushy and of erect plants gave a decrease in weight at the first picking of 15.6 per cent for the bushy, but with December pickings included, this was reduced to 5.2 per cent. In another test of 30 each, 13.2 per cent fewer bolls for the season were picked from bushy plants.

Control.—A satisfactory control for this insect on cotton has not yet been found, and the only recommendation that can be made is to practice field sanitation including thorough destruction of weeds in and around the fields before cotton is planted.

RED MITES, OR RED SPIDERS

Two mites—the two-spotted mite, *Tetranychus bimaculatus* Harvey, and the common red spider, *T. telarius* (Linn.)—each only about 1/64

Fig. 19.—Red-mite, or red-spider, injury to a cotton leaf.

inch long, are difficult to see without the aid of a magnifying glass. Most of the adults on cotton are amber-colored rather than red, with two irregular dark spots on the sides, but on some other host plants and in winter they are very red. The tiny, pale, spherical eggs and the mites are found in a very fine web on the surfaces of plants. The adults overwinter in trash and on weeds and other plants. A female lives[10] 7 to 10 days during the summer and deposits 50 to 60 eggs, which hatch in about 3 days. The young mature in 10 to 12 days.

[10] Essig, E. O. Insects of western North America. xi+1035 p. 766 figs. The Macmillan Company, New York. 1926.

Injury.—The injury to cotton is frequently confused with that done by the bean thrips, but the two are readily distinguishable under close examination of the leaves. A very fine web covers the surface of leaves on which these mites are feeding. Their feeding ruptures the green cells, and fine white specks result. The injured leaves later become reddened, and when this reddening becomes noticeable many cotton growers know the injury as "rust" (fig. 19). If the surface of a leaf is exposed to the direct rays of the sun, and the opposite surface is scratched, the mites will be disturbed so as to be seen moving. The bean thrips, on the other hand, always leaves small black spots of excrement on the silvery leaf surface; it does not spin a web, nor is the color of the leaf when injured the same as that of leaves injured by red spiders.

Red spiders are not closely associated with cotton suffering from drought nor with that grown on heavy or dark soils. Instead, they have been found more frequently on well-watered cotton. Infestations are noticeably associated with weedy, neglected ditches, roadsides, alfalfa fields, and deciduous fruit trees.

Control.—Where these mites are frequently a pest of cotton or other crops, field sanitation and attempts to destroy the overwintering adults should not be neglected.

Sulfur, when applied thoroughly to cover both upper and lower leaf surfaces, gives good control of these mites. The plants must be well cared for and growing vigorously or they may be killed by comparatively light infestations. Dinitrophenol dusts when thoroughly applied have given a good kill.

COTTON, OR MELON, APHID

The cotton aphid, *Aphis gossypii* Glover, is also known as the melon aphid. The adults are dark green with black appendages. The wingless forms vary in color, and may be yellow, green, brown, black, pinkish, or mottled and dull, according to the waxy covering. They are important pests of cotton throughout the summer and fall but are most serious in comparatively cooler periods and under humid conditions which are frequently due to excessive irrigation. They have many natural enemies, none of which can be relied upon for control.

Injury.—The amount of injury varies greatly from year to year in any one field, but certain localities at the southern extremity of the San Joaquin Valley and along the east side of the valley have this pest to contend with throughout the growing season almost every year. The dwarfing and killing of plants is only part of the injury. Perhaps more important is the sticky honeydew produced by the aphids, which falls onto the fiber of open bolls. The sooty-mold, or black-smut, fungus that

grows on the honeydew causes sooty-colored lint. The honeydew makes picking difficult and increases labor difficulties. Gin saws are gummed by this sticky fiber, especially when the humidity is high, and this clogging of gins may account for some of the difficulties in the spinning of fiber which are charged against irrigated cotton in the southwestern United States.

Control.—Dust and sprays containing from 1 to 2 per cent nicotine give good control. Two treatments within a week are usually necessary and they should be applied when the air is quiet and warm between late afternoon and sunrise.

COWPEA, OR BUR CLOVER, APHID

This aphid, *Aphis medicaginis* Koch, is shiny black with white legs and white at the base of the antennae. During the period of 1936–1939, except for the spring of 1939, it has been a serious pest on very young cotton.

Injury.—This insect is seldom found on cotton plants during the latter part of the growing season, but it is commonly present on cowpeas at all times. Where the aphids are abundant, young cotton seedlings are killed.

Control.—These insects may be controlled in the same manner as given for the cotton aphid.

COTTON SQUARE BORER

The adult of the cotton square borer, or bean lycaenid, *Strymon melinus* (Hbn.), is a butterfly with a wing expanse of 1 inch (fig. 20, *A*). The upper surfaces of the wings are velvety blue brown, the under surfaces silvery gray. The hind-wing margin is extended in two unequal, taillike projections, at the base of which are small orange and blue spots. The small, pearly greenish eggs are laid singly on the succulent growth of cotton, and larvae are found on the plants from May to November. The larvae (fig. 20, *B*) are velvety green, slug-shaped worms $\frac{7}{16}$ inch long when full-grown. In color they so closely resemble the green squares on which they feed that they are difficult to find. The larvae pupate (fig. 20, *C*) in folds of bracts on cotton squares and similar places in the foliage and form brown chrysalises slightly marked with darker spots. The pupae are about $\frac{3}{8}$ inch long and nearly as broad.

Injury.—The destruction of flower buds (fig. 20, *D*), small bolls, and occasionally succulent stems is not concentrated on one plant but is more or less uniformly distributed. This worm is the one most commonly found doing this type of injury in the San Joaquin Valley. Boll rots, caused

by worms which break the surface of bolls and permit two common fungi[11] to rot the entire boll, make this a more serious pest than is commonly recognized.

Control.—Destruction of stalks and weeds around fields from December to February by burning or plowing will kill many overwintering pupae on dead plants. Dusting with calcium arsenate dust, 6 to 8 pounds per acre, or the dusts containing calcium arsenate that have been recommended for control of cotton daubers, will control these.

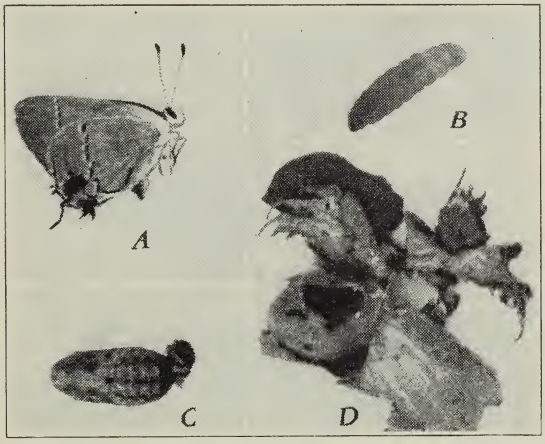

Fig. 20.—The cotton square borer, *Strymon melinus* (Hbn.): *A*, adult; *B*, larva; *C*, pupa; *D*, an injured cotton square. (All × 1.8.)

YELLOW-STRIPED ARMYWORM

The yellow-striped armyworm, *Prodenia praefica* Grote, is locally known as "the armyworm" (fig. 21). It occurs in destructive numbers in the middle or late summer and usually migrates from alfalfa to cotton. The adults are night-flying moths, gray to brown in color, the hind wings light silvery gray with a wing expanse of 1½ inches. The larvae are velvety black worms with yellow stripes along the sides, reddish beneath, and when full-grown are 1¾ to 2 inches in length.

Injury.—The worms feed on all the soft parts of the plant; they defoliate, cut off stems, and enter bolls, which if not completely eaten, will later rot. Migrations of worms occur mostly at night.

Control.—Recommendations for control are thorough cultivation in winter to kill overwintering pupae; building barriers of ditches with a

[11] Shapovalov, M. The two most common decays of cotton bolls in the southwestern states. Jour. Agr. Res. 35(4):307–12. 1927.

steep pulverized slope toward the infested field where they may be trapped and killed when migrating from alfalfa or other crops to cotton; and poisoning with bran mash made by either of the following formulas:

FORMULA 1

Bran	50 pounds
Molasses	2 quarts
Sodium fluosilicate	2 pounds
Water sufficient to make a dry mash	

FORMULA 2

Wheat bran or alfalfa meal	50 pounds
Paris green or arsenic trioxide	2 pounds
or calcium arsenate	4 pounds
Molasses	4 quarts
Water sufficient to make a dry mash	

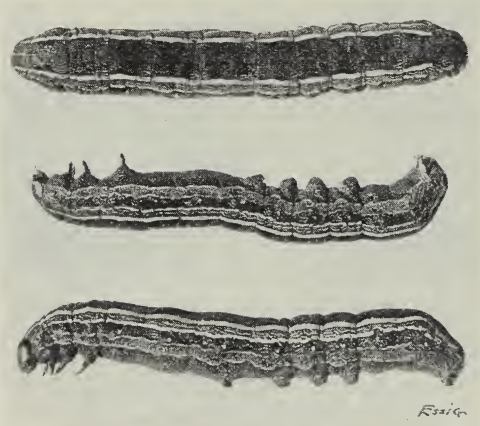

Fig. 21.—The yellow-striped armyworm, *Prodenia praefica* Grote (actual size). (From Ext. Cir. 61.)

If the worms are small and numerous on cotton plants, dust with 4 to 6 pounds of calcium arsenate per acre. If worms are nearly full-grown they will eat about as much cotton before being killed by the poison as they would if no control were used. Other arsenical dusts and sprays are also effective if used early enough. Standard lead arsenate sprays give good control and have shown no injury to cotton when used in hot weather at the rate of 3 pounds per 100 gallons.

ALFALFA CATERPILLAR

The caterpillars, *Eurymus eurytheme* (Bdv.), are smooth, bright-green worms with yellow stripes along the sides. The adult alfalfa butterfly (fig. 22) has a wing expanse of about 2 inches. They are usually

yellow to orange, but some pale forms occur. The wings are bordered with wide black bands, sometimes enclosing yellow spots, and a black spot occurs near the center of each fore wing. Two spots are present on the under surface of the hind wings. The butterflies are attracted by cotton flowers in midsummer and many cotton growers believe this to be the adult of the yellow-striped armyworm (p. 27). Conditions often

Fig. 22.—The alfalfa butterfiy, the adult form of the alfalfa caterpillar, *Eurymus eurytheme* (Bdv.). Worms are never found on cotton. (From Ext. Cir. 87.)

favor these two species so that the butterflies and the armyworms appear in large numbers. They are separate and distinct species of insects however. The alfalfa caterpillar does not feed on cotton.

COTTON BOLLWORM, OR CORN EARWORM

The cotton bollworm, *Heliothis armigera* Hbn. (formerly *H. obsoleta* [Fab.]) is also called the corn earworm (fig. 23). The adults are buff- or fawn-colored moths with a wing expanse of about 1½ inches. The wings are transversely banded with irregular darker bands. They visit many types of flowers to feed from sundown to sunrise. More than a hundred host plants are known but it is most destructive on corn (where

it is known as the corn earworm), cotton, tomatoes (where is it known as the tomato fruit worm), and tobacco. Eggs are laid singly by females from 3 days after emergence to death, and from 500 to 3,000 eggs may be deposited by a single female.[12] The larvae are about 1½ inches long when full-grown, smooth, and variously colored from pale greens and tans to brown or almost black. They are longitudinally striped with

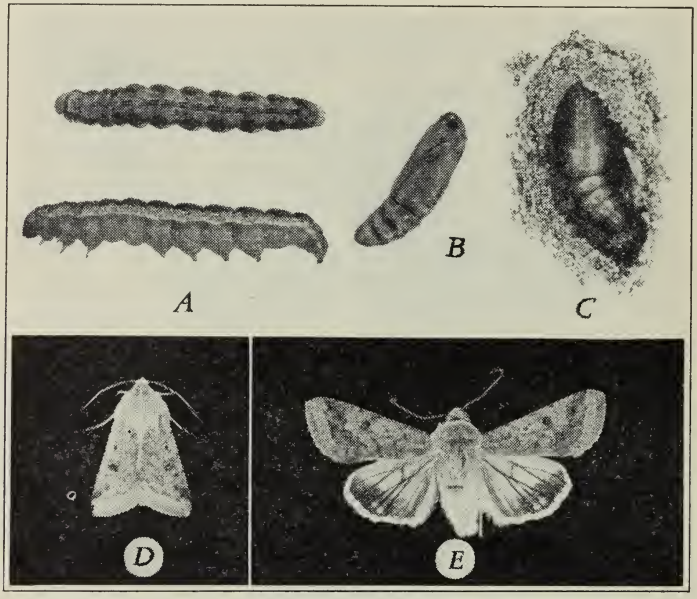

Fig. 23.—Stages in the life cycle of the cotton bollworm, or corn earworm, *Heliothus armigera* Hbn.: *A*, mature larvae; *B*, pupa removed from earthen cell; *C*, pupa within earthen cell; *D*, adult at rest; *E*, adult with wings spread. (All actual size.) (From Bul. 644.)

pink, yellow, or brown, and are cannibalistic. Under favorable conditions the worms become full-grown in two weeks and pupate in the soil, 2 to 10 inches below the surface. Overwintering pupae are found deeper in the soil than others. Moths emerge from the soil about the first of April.

Injury.—Worms feed on bolls and occasionally the small ones feed on buds. The worms enter the bolls usually beneath the bracts and may destroy the contents. They frequently move from one boll to another before there is noticeable injury, but if the surface or only one lock is injured, fungi may cause the entire boll to rot. Boll rots usually amount to 3 to 5 per cent of the crop in cotton fields of the San Joaquin Valley. Some fields show considerably less and others more than this. This boll

[12] Michelbacher, A. E., and E. O. Essig. Caterpillars attacking tomatoes. California Agr. Exp. Sta. Bul. 625:4–5. 1938.

rot is associated with all boll-feeding insects but more commonly follows the injuries made by chewing insects.

Control.—Thorough fall and winter plowing of land where cotton is to be planted will destroy pupae. Prevention of spring weeds, which serve as food for these worms, is also of value.

Trap crops of sweet corn have been investigated as a possible control procedure by many entomologists with results which vary greatly. The conclusions from all these tests indicate that corn must be in tassel and silk to be attractive to the moths and that after silks are dry the corn may be a source of infestation to near-by crops. The use made of the corn and maintaining the proper stage of growth by frequent planting will determine the practical value of this method.

Calcium arsenate dust may be applied at the rate of 4 to 6 pounds per acre when the air is calm and when the first bolls are forming. Close examination of the bolls will indicate the time of application where it is an occasional pest. If this pest is serious, 15-day intervals in applications should be the maximum. Other arsenical dusts and sprays have been used with good results. Sodium fluosilicate dusts have proved highly toxic and satisfactory. Poison baits have not given consistent control.

VARIEGATED CUTWORM

The variegated cutworm, *Lycophotia margaritosa* (Haw.), is one of many similar forms (fig. 24). The adult is a grayish brown, night-flying moth with a brassy luster and a wing expanse of 1½ to 2 inches. The eggs are laid from late February until October in large clusters of 400 to 500 and in various locations (fig. 24, *B*). The worms hatch in 4 to 10 days, according to the temperature, and young larvae find their way to suitable food, which is almost any green plant. When the larvae are full-grown they are 1½ to 2 inches long, usually grayish brown with a darker, longitudinal, narrow stripe down the back and mottled spotting on the sides. The ventral surface is uniformly light brown.

Injury.—This is one of the cutworms found in cottonseed trash and in late bolls feeding on foliage or killing seedling plants.

Control.—For the control of this and other cutworms, the fields should be plowed and thoroughly worked as soon as possible after the crop is picked. Weedy areas in or near the fields should be cleaned up in the spring, by plowing and deep disking.

Poison bran mash, as given under "Yellow-striped Armyworm" (formula 2, p. 28), is the recommended chemical control for this and other cutworms.[13]

[13] Folsom, J. W. Insect enemies of the cotton plant. U. S. Dept. Agr. Farmers' Bul. 1688:24. 1932.

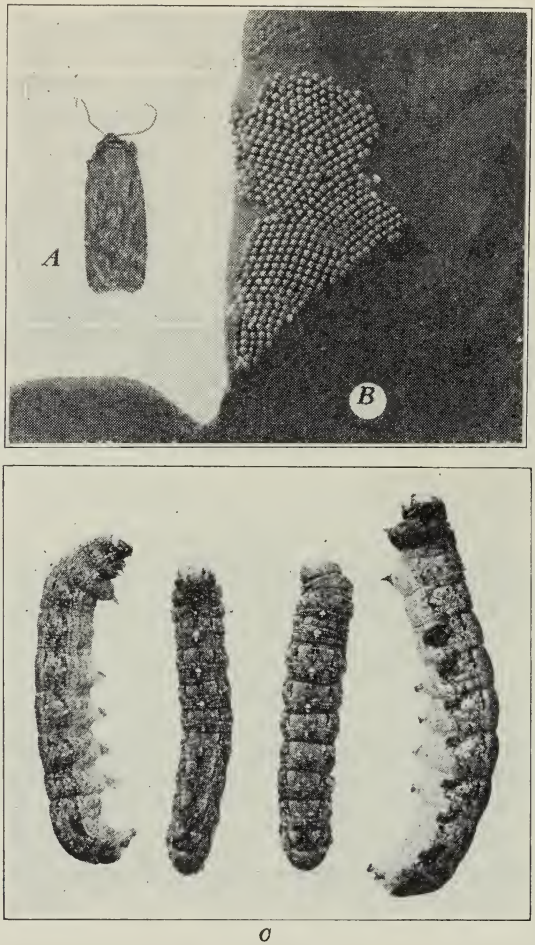

Fig. 24. — The variegated cutworm, *Lycophotia margaritosa* (Haw.): *A*, adult at rest (actual size); *B*, eggs of the variegated cutworm on a cotton leaf (×10); *C*, larvae, or caterpillars (×1) (from Ext. Cir. 87).

ALFALFA LOOPER

The moths of the alfalfa looper, *Autographa californica* (Speyer), have a wing expanse of 1¼ to 1½ inches. The fore wings are mottled gray brown with a silvery "gamma" mark at the middle of each (fig. 25, *A*). The body and hind wings are light brown. The females lay eggs on cotton plants during the night throughout the season, and the resulting green worms move about in a looping, or measuring-worm, manner (fig. 25, *B*), eating holes in leaves. They are most abundant in May and late

July or early August. They pupate in a silken web on the lower surfaces of cotton foliage, usually in folds of leaves or bracts.

Injury.—The destruction of foliage on young plants and delaying of early growth is of more importance than later injury. None of this injury is ordinarily serious, although in some fields where insects are abundant, losses may occur.

Control.—The destruction of plants soon after harvest by burning or plowing under the pupae on the stalks and foliage is a desirable prac-

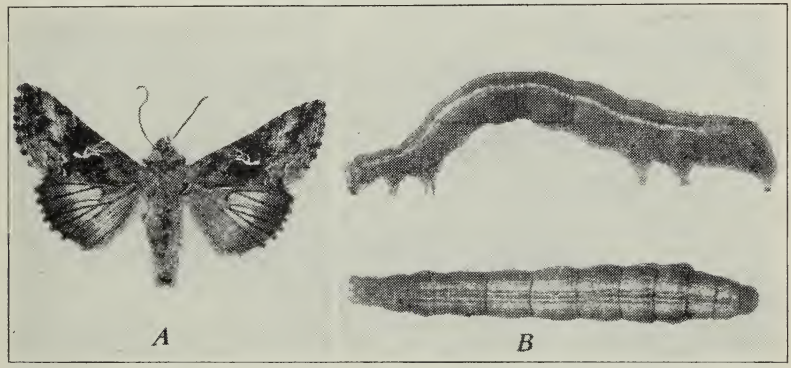

Fig. 25.—*A,* Adult alfalfa looper, *Autographa californica* (Speyer) (actual size); *B,* larvae (×2) (photograph by A. E. Michelbacher).

tice, but if alfalfa and other crops are not worked so as to destroy the overwintering pupae on the stubble, little can be accomplished. The arsenical and fluosilicate dusts should give satisfactory control on cotton if an insecticide is necessary.

WHITE-LINED SPHINX

A species of hornworm—the white-lined sphinx, *Celerio lineata* (Fab.) (fig. 26, *B*)—has given cotton growers and others trouble during the spring by eating the buds and young foliage. The adult, also known as a hummingbird moth (fig. 26, *A*), has a wing expanse of 3 to 3½ inches; the fore wings are buff with fine white lines and the hind wings have a wide rose-colored band. It hovers over flowers in the evening feeding on nectar as does a hummingbird. The worms are 3 inches long when full-grown with a yellow horn at the posterior end. The colors of the worms vary from pale green to black with dusky spots and narrow white stripes. They migrate over considerable distances and feed on most green plants.

Injury.—The worms kill cotton seedlings by eating the foliage and stems.

Control.—In order to protect the cotton fields from the white-lined sphinx, barriers should be built between the fields and the source of infestation; a steep-sided ditch may be used, with a built-up bank of pulverized soil on the side away from the infested field. This barrier will hold them where they may be destroyed by crushing or oiling.

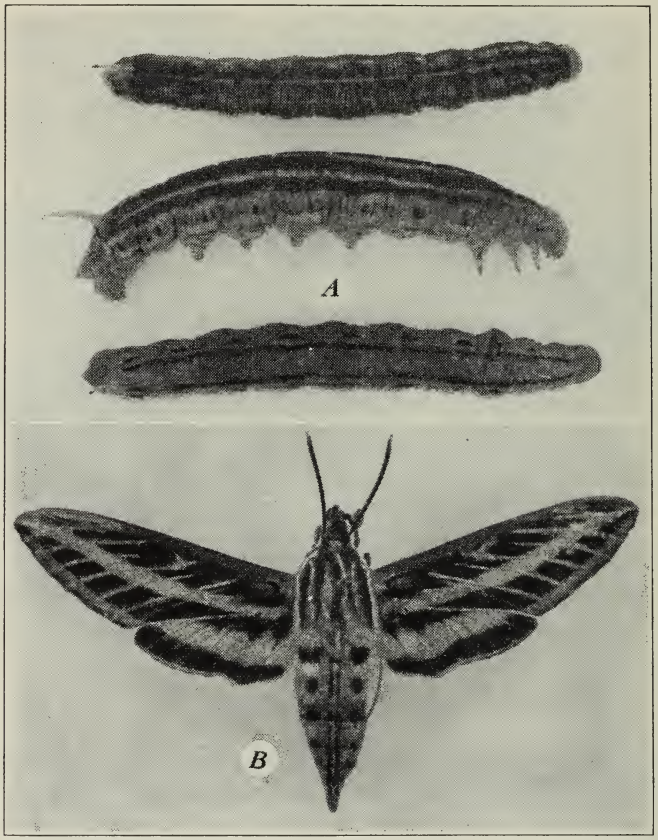

Fig. 26.—The white-lined sphinx, *Celerio lineata* (Fab.): *A*, larvae (hornworms); *B*, moth. (Both actual size.)

Postholes dug at intervals along the ditch will help to trap them. In areas where many spring wild flowers bloom, examination of these plants in early April will indicate whether or not there will be many of these worms. Many wild flowers have been examined and small worms have been found on several of these plants.

If the worms are already in cotton fields before they are discovered, poisons may work so slowly in destroying them that most of the plants may be killed. Several ingenious methods of crushing them in the fields

have been suggested but not thoroughly tried. One which gives promise is the use of a flat-tired wheel sufficiently heavy to crush the worms and yet not seriously injure the cotton seedlings in the row. The cotton seedlings are not broken or injured if this is done when the temperature is 70° and higher. Cryolite, lead arsenate, calcium arsenate, and fluosili-

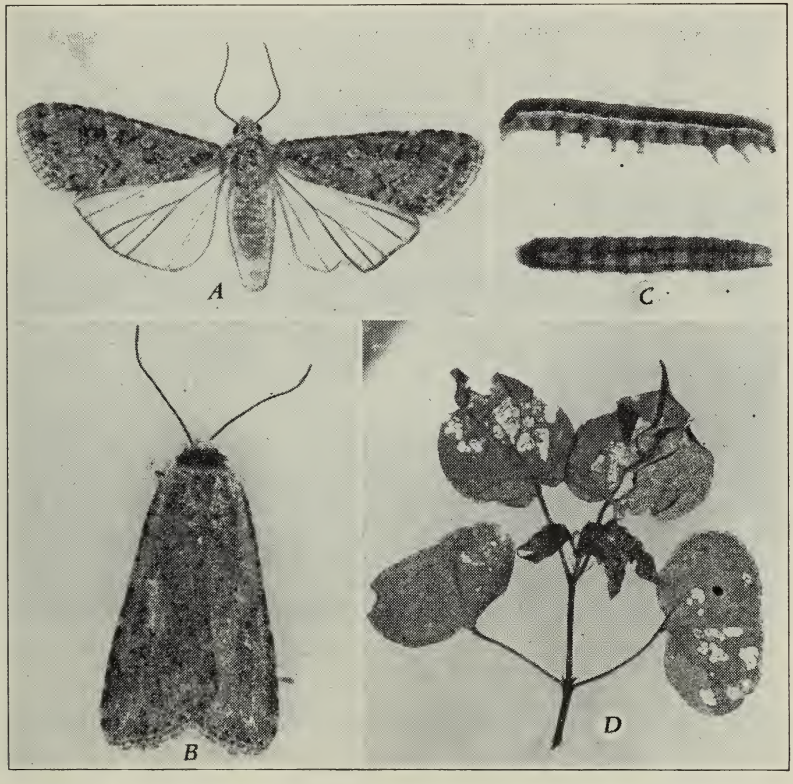

Fig. 27.—The beet armyworm, *Laphygma exigua* (Hbn.): *A*, adult (×2.2); *B*, adult at rest (×2.5); *C*, larvae (×1.5) (photograph by A. E. Michelbacher); *D*, injury to cotton seedling.

cates in dusts and sprays are effective in killing these worms but their use is advisable only when the worms are small.

BEET ARMYWORM

The moth of the beet armyworm, *Laphygma exigua* (Hbn.), is mottled gray with light markings (fig. 27, *A*) and a wing expanse of about 1 to 1¼ inches. The worms (fig. 27, *C*) are 1 to 1¼ inches long when mature, pale olive green in color, with a dark stripe down the back and pale stripes on the sides. Considerable variation in color occurs.

Injury.—Outbreaks of these worms, which skeletonize the leaves and defoliate plants, occur in May and late July or August. The early brood is more likely to have serious effect on small plants, but usually not enough injury is done to require control.

Control.—Clean cultural practices to destroy pupae and prevent weedy areas where the insects may feed and build up in numbers is recommended. In several instances effective control has been obtained

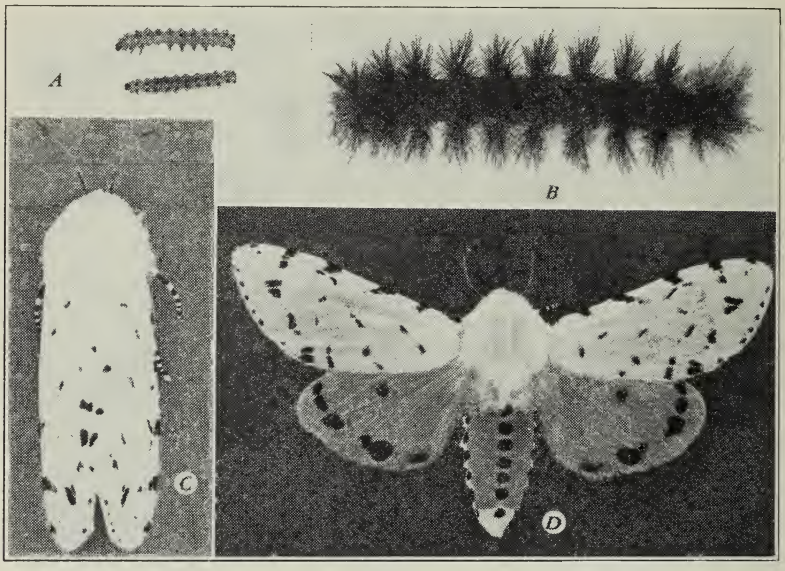

Fig. 28.—The salt-marsh caterpillar, *Estigmene acraea* (Drury): *A*, young larvae (×2); *B*, mature larva (×1); *C*, adult at rest (×1.5); *D*, adult (×1.2).

by knocking the insects off the plants by sacks attached to the cultivator. If the temperature of the soil is high the control is improved. Arsenical and fluosilicate dusts or sprays are effective in killing the worms.

SALT-MARSH CATERPILLAR

The white moths of the salt-marsh caterpillars, *Estigmene acraea* (Drury) (fig. 28, *C, D*), have a wing spread of about 2¼ inches and a body length of about 1 inch. They are white with orange abdomen which is banded with black, and with black spots on the wings. The hind wings of the males are orange. Eggs are laid in masses on many green weeds and cultivated plants. The larvae (fig. 28, *A, B*) are at first light in color with long darker hairs in clusters covering the body. When mature, these "wooly bears," known as salt-marsh caterpillars, are about 2 inches in length and dark reddish brown with broken yellowish bands. The

mature worms overwinter in trash and other protected places. Pupation occurs in the early spring.

Injury.—Only late-summer injury to cotton has been seen two years during the past five in the San Joaquin Valley and this occurred in spots along the west side of the Valley. The insect also occurs in large numbers along the Colorado River.

Control.—Folsom of the United States Department of Agriculture states: "Control of weeds around cotton fields is a logical method of checking this and many other cotton insects."[14] He also recommends that if an insecticide is needed, the use of calcium arsenate at 5 pounds or more per acre or other arsenical dusts is effective. Except for unusual outbreaks, insecticides will not be economical for control of this pest alone.

COTTON LEAF PERFORATOR

Adults of this insect, *Bucculatrix thurberiella* Busck, are tiny, white, slender moths about ⅛ inch long. The oblong, yellow eggs are attached at the end to the leaves. The small green worms have black spots and white tubercles distributed over the body. The larvae are first leaf miners and tunnel irregular courses through the leaf tissues. They then eat holes through the leaf and thus give it a lacelike appearance before they pupate on the plant in white ribbed cocoons. According to Folsom, "The period required for development from egg to adult ranges from about 15 to 70 days, according to the season. It averages 18 days, and there is a possibility of 9 or 10 generations annually in the Imperial Valley."[15] Cultivated cotton and wild cotton, *Gossypium Thurberia* Tod., are the only known host plants of this insect.

Injury.—The partial or complete defoliation of cotton causes the bolls to open prematurely and produce low-grade fiber, and the buds, small bolls, and flowers to fall from the plants. This injury occurs in Riverside and Imperial counties every year and is frequently serious. This and other insect pests of cotton have reduced the cotton acreage in these counties. The cotton leaf perforator is not found in the San Joaquin Valley.

Control.—Probably the discontinuance of stub or volunteer cotton would be of considerable value in control. The insect was found in all stages of development on volunteer cotton on March 22, 1937, at Blythe, California. Dusting with powdered lead arsenate 5 to 7 pounds per acre has been recommended, but thorough underleaf coverage must be ob-

[14] Folsom, J. W. Insect enemies of the cotton plant. U. S. Dept. Agr. Farmers' Bul. 1688:20. 1932.

[15] Folsom, J. W. Insect enemies of the cotton plant. U. S. Dept. Agr. Farmers' Bul. 1688:15. 1932.

tained. Reports from southeastern California indicate that satisfactory control has not been obtained.

BROWN COTTON BUG

The adults are stink bugs, *Euschistus impictiventris* Stål, almost ½ inch long and 5/16 inch broad, flat across the back, convex beneath, entirely brown with sharp shoulder projections. It is one of the serious pests of cotton, but in California only in Riverside and Imperial counties.

Injury.—The brown cotton bug causes injury similar to that done by Say's stink bug, but the injury is more serious.[16]

CREONTIADES FEMORALIS

The adults of *Creontiades femoralis* Van D. are about ¼ inch long and little more than 1/16 inch broad, reddish brown with long antennae and legs. They belong to the same family as the cotton dauber and are found on both cotton and alfalfa in Riverside and Imperial counties.

Injury.—Cassidy and Barber[17] report that this insect "has given indications of considerable economic importance in cage experiments" and that it does not occur in large numbers. The injury produced is deformed plants and reduction of yield.

WHITEFLIES

The larvae of whiteflies (fig. 29) are small scalelike insects which are found in great numbers on the lower surfaces of cotton leaves in some localities and under certain conditions. The abundance of honeydew secreted by them causes the same type of injury as that from aphids. Growers usually refer to these as "aphids" because of the honeydew. The adults are about 1/16 inch long and the wings are covered with fine, white, powdery wax. The larvae are cream or white, 1/25 inch long and almost as broad. Three species, *Trialeurodes pergandei* (Quaint.), *T. vaporariorum* (Westwood), and *T. abutilonea* (Haldeman), have been collected from cotton but *T. pergandei*, which has no common name, is the only one that has been of much importance in cotton fields. This species builds up on a matlike weed that grows on ditchbanks and field borders, especially next to the desert on the south and west sides of the San Joaquin Valley.

[16] Cassidy, T. P., and T. C. Barber. Hemipterous cotton insects of Arizona and their economic importance and control. U. S. Dept. Agr. Bur. Ent. and Plant Quarantine Mimeo. **E-439**:2–3. 1938.

[17] Cassidy, T. P., and T. C. Barber. Hemipterous cotton insects of Arizona and their economic importance and control. U. S. Dept. Agr. Bur. Ent. and Plant Quarantine Mimeo. **E-439**:3. 1938.

Injury.—Honeydew causes difficulties as described under "Cotton, or Melon, Aphid," but plant growth is only slightly retarded.

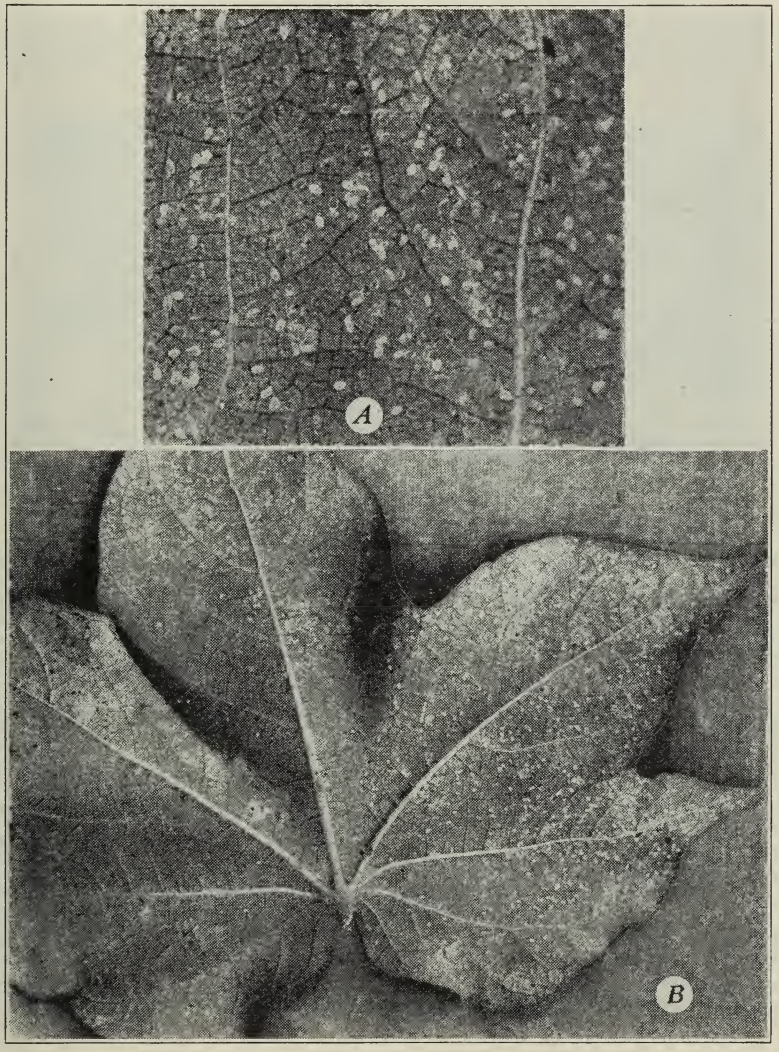

Fig. 29.—Whiteflies, *Trialeurodes abutilonea* (Haldeman), on a cotton leaf; *A* shows an enlarged portion of leaf shown in *B*.

Control.—Destroy the matlike weeds, *Euphorbia ocellata* D. & H., early in the season, approximately up to July 1. Do not attempt this method of control after August 1 because destruction of the weeds at this time will cause a migration of whiteflies to cotton plantings.

WESTERN TWELVE-SPOTTED CUCUMBER BEETLE.

These beetles, *Diabrotica soror* Leconte (fig. 30), have shiny green wing covers with 12 black spots; the rest of the body and appendages are mostly black. It is often erroneously referred to as the "green lady-

Fig. 30.—The western twelve-spotted cucumber beetle, *Diabrotica soror* Leconte, and its work on leaves of watermelon (× 2). (From Ext. Cir. 87.)

bird beetle." They are the adult form of white larvae which feed on the roots of both cultivated and wild plants.

Injury.—This beetle eats holes in the foliage, flowers, and buds. It is a minor pest of cotton.

Control.—Calcium arsenate and fluosilicate dusts are very effective for the control of this insect. A dust consisting of a mixture of about

1 per cent aliphatic thiocyanate and pyrethrum extract (0.10 per cent pyrethrins) is also very effective.

SMALL DARKLING GROUND BEETLES, OR FALSE WIREWORMS

The adults are dark, flat beetles (fig. 31), ¼ inch long and one half as broad. The most important of these small darkling ground beetles in

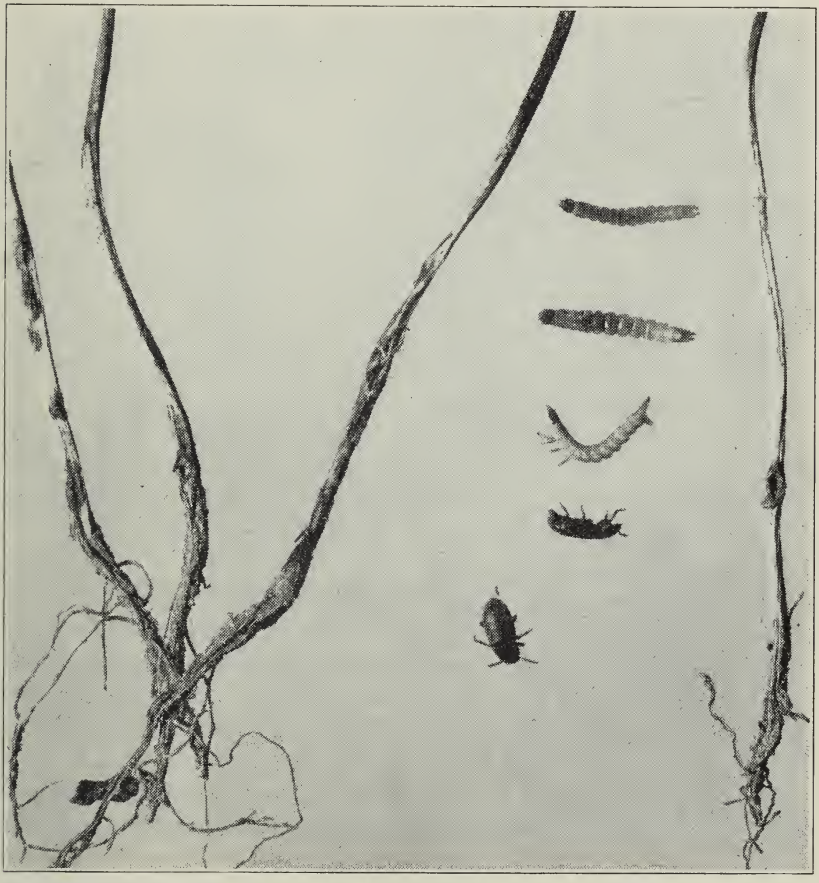

Fig. 31.—The small darkling ground beetles, *Blapstinus rufipes* Casey, the larvae (false wireworms), and cotton seedlings killed by these. (All × 1.5.)

the San Joaquin Valley is a red-legged one, *Blapstinus rufipes* Casey. Because the larvae somewhat resemble wireworms they are called "false wireworms." The larvae are difficult to see because they are much the same color as the rootlets and are usually found in cracks, under particles of soil, and feign death when disturbed. The larvae are slender, light-colored worms, ½ inch long and 1/16 inch broad when full-grown,

with dark-brown head and posterior tip (fig. 31). These are more numerous in light sandy soils than in other types and are especially abundant in the soil on which alfalfa or some other legume covercrop has been grown the preceding summer.

Injury.—False wireworms collect around germinating cotton seeds and can be found inside the seed coat or hull, inside the seedling stem, or near seedlings where they may only mar the surface of the stems (fig. 31). The adults may eat only small portions of the seedling stem near the soil surface or may cut the plant off. Close examination of dead and dying seedlings will help to distinguish some of this loss of stand from that due to sore shin, a damping-off disease of cotton. Any break in the surface of the stems and roots by insects makes an entrance through which these fungi can attack the plants and kill them. Cool moist weather, wet soils, and covercrops grown the preceding summer are conducive to sore shin. This disease may, of course, attack plants in cases where there are no insects involved.

Control.—The adults may be controlled with poison bran baits, or by dusting plants heavily with lime. If calcium arsenate or cryolite dusts are used, lighter applications are sufficient.

The use of seed treated with organic mercury compounds gives promise in protecting plants from early false-wireworm injury and subsequent sore shin.

Fig. 32.—Large darkling ground beetle, *Eleodes* sp. (actual size).

LARGE DARKLING GROUND BEETLES

Local outbreaks of large spindle-shaped shiny black beetles of the genus *Eleodes* (fig. 32) have occurred in areas near pastures where cattle graze. Great numbers of these beetles migrate from pasture lands into fields and have caused considerable alarm and frequently have injured foliage of many crops including cotton. The beetles are ¾ to 1 inch long and about ⅜ inch broad, black throughout, with long legs. When disturbed the head is lowered to the ground and the body held at a 45-degree angle. An offensive odor is emitted from the glands at the end of the body. The larvae are found in the soil of pasture lands. They feed on both decaying organic matter and on roots of grains and grasses.

Injury.—Destruction of cotton seedlings by adults, which eat the tops of the plants, is localized and not extensive.

Control.—Barriers of straw or refuse between the field and the migrating insects will serve for protection from the sun during the day. Oiling and burning to destroy the insects under this barrier are effective. Barriers of steeply banked loose soil with postholes in which the beetles collect, ditches with water or oil on water, and the use of flame throwers in combination with these, all help in control.

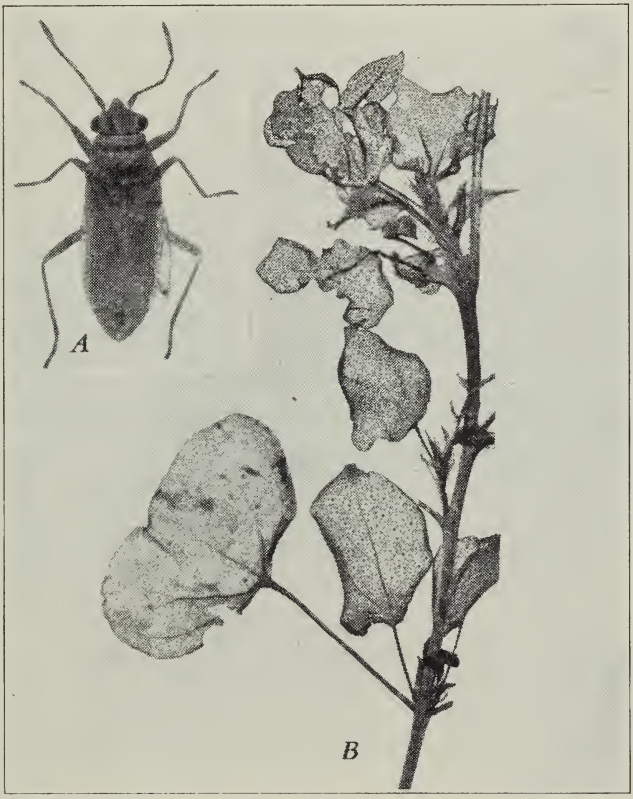

Fig. 33.—*A*, False chinch bug, *Nysius minutus* Uhl. (×10); *B*, a seedling cotton plant injured by these bugs.

Poison bran baits scattered in the evening along the edges of the fields near pastures will poison large numbers of the adults.

FALSE CHINCH BUG

The adult false chinch bug, *Nysius minutus* Uhl. (fig. 33, *A*), are ⅛ inch long and about one third as broad, with silvery gray wings. The body is dark brown to black and the legs slightly lighter brown. They breed chiefly in grasslands but swarm on cotton in the early spring in

such enormous numbers that they may kill small cotton plants. More injury has been observed on flax than on any other crop. The tiny nymphs may be found in late March and April in grasslands and flax fields so numerous that the ground is a squirming mass of these reddish-brown bugs.

Injury.—The gregarious habits of these bugs cause them to concentrate in areas where all the cotton seedlings will be killed or seriously injured (fig. 33, *B*). This is most common next to grasslands but spots frequently occur in fields far from grasslands. The plant is attacked by so many insects that it turns brown as though burned.

Control.—Burning grass and weeds along the edges of fields where the insects concentrate, frequent cultivation, irrigation, or flooding in fields when practical, will kill many nymphs. One pint of nicotine sulfate solution, 40 per cent (such as Black Leaf 40) in 100 gallons of water with 4 to 5 pounds of fish-oil soap, or 25 per cent calcium cyanide dust if air conditions are suitable, are the best-known chemical controls.

COTTON INSECTS OF LITTLE OR NO IMPORTANCE IN CALIFORNIA

Fruit Notoxus.—These small, light- and dark-brown banded beetles, *Notoxus constrictus* Casey (fig. 34, *A*), are about ⅛ inch long, one third as broad, and appear on cotton at the time the first squares form in late June. Though found in great numbers and often thought to be pests of cotton, in all segregation tests no injury has been found. The fruit notoxus feeds on the sweet sap or glandular exudates from glands at the bases of the three bracts of a square, or boll, and on the three glands of the undersides of leaves. The prothorax, or that portion of the body just behind the head, extends in a hornlike, projecting hood over the head, a peculiar structure which will help to distinguish this beetle from others. It will also be found feeding on many other plants and especially fruits where sweet secretions or juices are available. Others of these antlike flower beetles occur on cotton but are not so numerous nor conspicuous as this one. No larva forms have been found on cotton.

Green Leafhoppers.—Slender green leafhoppers (fig. 34, *C*) occur in great numbers on cotton and other crops in the San Joaquin Valley. Those which have been taken from cotton and submitted to D. M. De Long for identification are *Empoasca filamenta* De Long. They are about ⅛ inch long, bright green, and found with their nymphs on the lower surfaces of leaves. Growers often refer to these as "vine hoppers," but the "vine hopper" is the grape leafhopper, *Erythroneura comes* (Say), which is light brown or tan with red veins in the wings and is rarely

found on cotton. In a recent publication De Long[18] shows that other species of bright-green leafhoppers closely resembling this one also occur in this area.

The tests made by segregating this insect on cotton have not shown decreases in yield nor very marked changes in plants. Sap is sucked from the leaves and the feeding areas are whitened. Frequently an entire plant becomes a lighter color. Green leafhoppers may be numerous on potatoes without causing hopper burn, but they seriously injure watermelons by killing the foliage. When cotton is killed in the fall they mi-

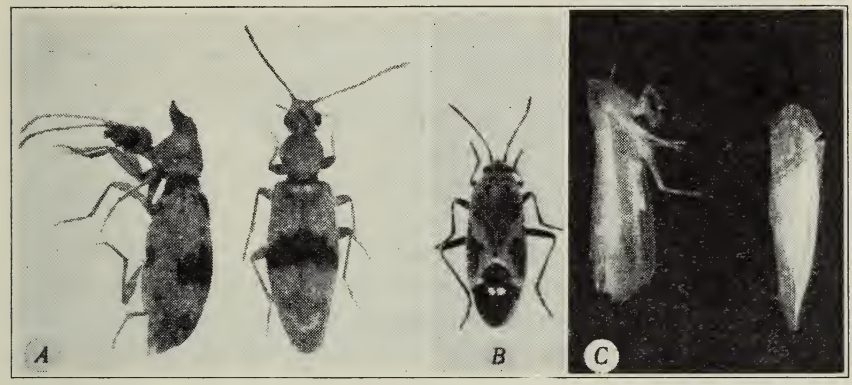

Fig. 34.—Insects frequently found on cotton in the San Joaquin Valley which are of little or no importance there: *A*, fruit notoxus, *Notoxus constrictus* Casey (× 10); *B*, common milkweed bug, *Lygaeus reclivatus* Say (× 2); *C*, slender green leafhopper, *Empoasca filaminta* De Long (× 10).

grate to plants that are green throughout the winter and cause white spots on oranges, on leaves of other winter crops, and on weeds. These hoppers stay close to the ground during the coldest weather. In cotton they are always much more numerous in rank, shady growths. On watermelons, extract-of-pyrethrum dusts were effective in control, but strong nicotine dusts were not.

Saltbush Stink Bug.—This insect, *Thyanta punctiventris* Van D., is often found in cotton fields and is the cause of many inquiries. It is shaped like Say's stink bug but is only ¼ inch long and dull gray green in color. Its preferred host plant is saltbush, *Atriplex* spp., commonly known as "sagebrush" in the San Joaquin Valley. All attempts to rear this insect on cotton alone have failed. In 1935 when all plant bugs were very numerous in this Valley, this insect was reported from many cotton fields, but no specific injury was evident on mature plants. Cotton seed-

[18] De Long, D. M. Biological studies on the leafhopper, *Empoasca fabae*, as a bean pest. U. S. Dept. Agr. Tech. Bul. 618:8. 1938.

lings growing in fields near saltbush have been killed by the nymphs and adults. It is rarely, however, a pest of cotton.

Small Green Stink Bug.—The small green stink bug, *Thyanta brevis* Van D., is the same size as *T. punctiventris* but is light, shiny green in color, and is found on saltbush and also on other native growths. It was very numerous on many crops and weeds in 1935 but is found only occasionally during most seasons. It does not breed on cotton.

Common Milkweed Bug.—This bug, *Lygaeus reclivatus* Say (fig. 34, *B*), is 7/16 inch long and 1/8 inch broad. The antennae, legs, head, and thorax are velvety gray black. The abdomen is red with dark spots and dark tip. The membranous parts of the wings are black-bordered with white and with two circular white spots near the center of each. The basal portions of the wings are red and black. The scutellum is black and the pronotum red and black. This insect is mentioned because it is frequently found in cotton and is sometimes thought to be a cotton stainer, *Dysdercus* spp. It does not breed on cotton. The adults have produced some injury to the bolls when confined on cotton branches in thin cloth cages; it is not a serious cotton pest.

Spotted Milkweed Bug.—This insect, *Oncopeltus fasciatus* (Dallas), is found in cotton fields but not so frequently as the preceding one. It is 9/16 inch long and has three large black spots on the red back. It is not a cotton pest.

IMPORTANT COTTON INSECT PESTS NOT FOUND IN CALIFORNIA

The following list of insects includes serious pests of cotton outside of the state of California. The pink bollworm, *Pectinophora gossypiella* Saund., is the most serious pest of cotton in the world, but it is not so well established in the United States as is the boll weevil, *Anthonomus grandis* Boh. In cotton literature any of these insects may be referred to, and the descriptions of them and their injury to cotton may lead one to believe that the insect is present in California. Those who have been engaged in the cotton industry outside of this state often see insects which they believe to be one of these serious cotton pests.

Boll weevil, *Anthonomus grandis* Boh.
Thurberia weevil, *Anthonomus grandis* Boh. var. *thurberiae* Pierce
Cotton leaf worm,[19] *Alabama argillacae* Hbn.
Pink bollworm, *Pectinophora gossypiella* Saund.

[19] Has been reported from southeastern California, but uncertainly.

Cotton stainer, *Dysdercus suturellus* (H. S.); other species of this genus.—*D. mimus* (Say); *D. albidiventris* Stål., *D. obliquus* H. S.—are listed as occurring in California[20] but are not known as important cotton pests here
Rapid plant bug, *Adelphacoris rapidus* (Say)
Cowpea curculio, *Chalcodermus aeneus* Boh.
Frankliniella tritici (Fitch)
Sand wireworm, *Horistonotus uhlerii* Horn
Wireworm, *Monocrepidius vespertinus* Fab.
Corn root aphid, *Anuraphis maidi-radicis* (Forbes)

SOME BENEFICIAL INSECTS COMMONLY FOUND ON COTTON IN THE SAN JOAQUIN VALLEY

There are numerous predatory insects, common spiders, and also parasitic insects attacking cotton pests that have not been mentioned nor illustrated in this paper; some of the more important ones, however, are given below.

Big-eyed Bugs.—These insects, *Geocoris pallens* Stål, and *Geocoris* spp. (fig. 35, *E*), are often very numerous on cotton but in no case have they been found injuring the plants. They feed on the nymphs of the cotton daubers and fleahoppers and also on eggs of the cotton daubers. The species found most abundant, *G. pallens,* is about 1/8 inch long, dark brown, the membranes of the wings forming a triangular silvery spot at the posterior. The eyes are large, very dark, and protruding. They move very rapidly over the plant surfaces. The biology of these predaceous big-eyed bugs has not been thoroughly studied. The eggs are laid singly on cotton plants and the nymphs resemble the adults in habits and shape. In color they are brownish green with small black spots on the back.

In 1938 when the cotton daubers were numerous and seriously reduced the crop, the big-eyed bugs were comparatively scarce in cotton fields until late in the season. In 1939 they were numerous on cotton throughout the season, and cotton daubers were of less importance than in any of the preceding three seasons. In 1940 these predators were again numerous on cotton, and the cotton-dauber-nymph population was small until late July. These predators have been resistant to the insecticides used for controlling cotton daubers.

Minute Pirate Bugs.—Because these small, predaceous insects, *Orius tristicolor* (White), *Orius* spp., and *Anthocoris* spp. (fig. 35, *D*), are known to feed on many kinds of insects, insect eggs, and mites and their eggs, they are called "minute pirate bugs." The one found most commonly on cotton here, *O. tristicolor,* is 1/16 inch long, flat, ovate, black

[20] Van Duzee, E. P. Catalogue of the Hemiptera of America North of Mexico. Univ. California Pubs. Ent. 2:207–9. 1917.

with the transparent parts of the wings forming three triangular silvery spots on the back, the head narrow and sharpened toward the front. This species is found most frequently feeding on thrips. Cotton growers and others who make close observations on the development of bean thrips

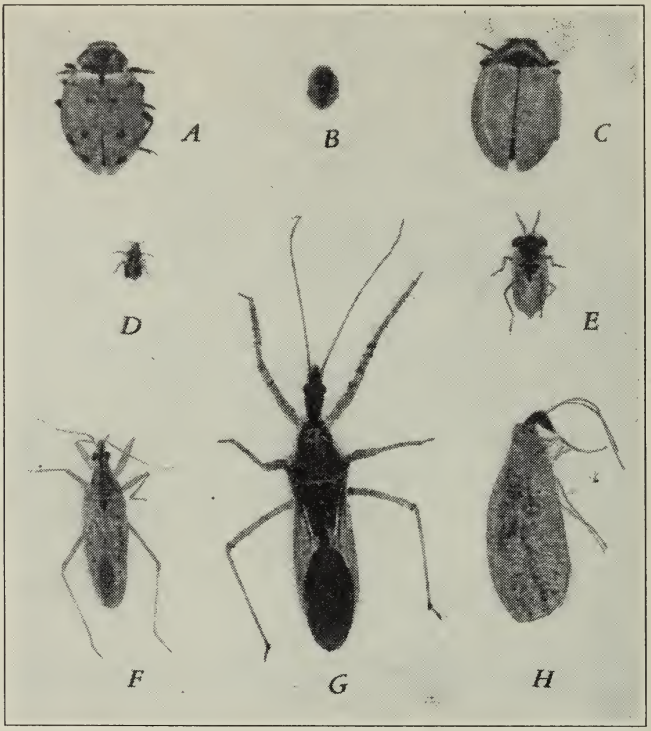

Fig. 35.—Some beneficial insects commonly found on cotton in the San Joaquin Valley. *A–C*, Ladybird beetles: *A*, *Hippodamia convergens* Guérin; *B*, *Scymnus* sp.; *C*, *Coccinella californica* Mann.; *D*, minute pirate bug, *Orius tristicolor* (White); *E*, big-eyed bug, *Geocoris pallens* Stål; *F*, damsel bug, *Nabis ferus* (Linn.); *G*, assassin bug, *Zelus exsanguis* (Stål); *H*, brown lace-wing, *Hemerobius* sp. (All × 3.)

in cotton fields observe the nymphs of this predator more frequently than the adults. The nymphs are deep yellow to orange in color and shaped like the adults.

Assassin Bugs.—The long-legged assassin bugs, *Zelus exsanguis* (Stål), *Zelus* spp., and *Sinea diadema* (Fab.) (fig. 35, *G*), move slowly around on plants, stalking their prey. Their forelegs are spiny and covered with a sticky fluid. The greenish nymphs are ungainly-looking creatures with their slender, spiny bodies and legs. The females of *Zelus*

species, found most numerous on cotton, are about ½ inch long and little less than ⅛ inch broad; the males are slightly smaller. They are light brown above, green beneath, with the basal part of the wings and the back of the body beneath the wings, blood red. The eggs are laid in a nearly circular, sticky brown mass, the upper surface covered with a very thin, white, sticky waxy coating. They feed on both injurious and beneficial insects with no observed preference for any types.

Damsel Bug.—This light grayish-tan bug, *Nabis ferus* (Linn.) (fig. 35, *F*), somewhat resembles an assassin bug, but the legs and thorax are less prominent. It is ¼ to 5/16 inch long; the nymphs resemble the adults except that they are wingless. It preys on many beneficial and injurious insects including cotton-dauber nymphs, aphids, and leafhoppers.

Ladybird Beetles.—The adults of the ladybird beetles, *Hippodamia convergens* Guérin (fig. 35, *A*), *Coccinella californica* Mann. (fig. 35, *C*), *Olla abdominalis* (Say), and *Scymnus* spp. (fig. 35, *B*), are usually readily recognized by almost everyone, but the larvae are often mistaken for pests. The more common ones found on cotton are red and black with small white markings in the adults and the larvae are flat, elongate, black with considerable orange spotting, ¼ to 5/16 inch long when mature and one third as broad. The ashy gray ladybird beetle, *O. abdominalis,* is close to 3/16 inch long and one third as broad, and gray with black spots. The small black ladybird beetles found on cotton are hemispherical, 1/16 to 3/32 inch in diameter, and the larvae resemble mealybugs because of the covering of white fuzzy wax. The eggs of the species *H. convergens, C. californica,* and *O. abdominalis,* most commonly observed on cotton, are masses of bright yellow, elongated, and attached at one end to the under surfaces of leaves or other parts of the plant. Aphids and mites are the chief food of these insects.

Green and Brown Lacewings.—The larvae and eggs of the green lacewings, *Chrysopa californica* Cog. and *C. majuscula* Banks, will be found where aphids are on cotton. Since the larvae often feed on aphids they are known as "aphid lions." They are ⅜ inch long, spindle-shaped but flattened, yellow or grayish, mottled with brown, and have two long sickle-shaped jaws. The eggs are ovate, white, and attached to the leaf by a long slender stalk. The body of the adult is very slender, ½ to ¾ inch long, and bright green. The antennae are long and slender, the wings large, broad, and delicate.

The brown lacewing, *Hemerobius* sp., illustrated in figure 35, *H*, is a species similar to the green lacewing.

ACKNOWLEDGMENTS

The investigations of cotton insects in California have been greatly aided, in fact made possible, by the coöperation of members of the United States Department of Agriculture Cotton Field Station at Shafter, California. The author gratefully acknowledges the continued interest and assistance that has been accorded him by the Field Station superintendent, George J. Harrison.

The author wishes to express his appreciation of the collaboration of the United States Department of Agriculture, members of the staff of the University of California Agricultural Experiment Station, farm advisors, agricultural commissioners, growers, insecticide companies, student assistants, and to Dr. G. F. MacLeod, for his assistance with the manuscript.

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